

AARC Clinical Practice Guideline

Spirometry—1996 Update

S 1.0 PROCEDURE:

Spirometry (S): The first American Association for Respiratory Care (AARC) Spirometry Clinical Practice Guideline,(1) published in 1991, was based largely on the American Thoracic Society (ATS) 1987 recommendations.(2) Since that time, the ATS has published new recommendations.(3) This updated AARC Clinical Practice Guideline not only reflects these new ATS recommendations but also contains additional recommendations on the use of bronchodilators in conjunction with spirometry.

S 2.0 DESCRIPTION/DEFINITION:

The objective of spirometry is to assess ventilatory function. Spirometry includes but is not limited to the measurement of forced vital capacity (FVC), the forced expiratory volume in the first second (FEV₁), and other forced expiratory flow measurements such as the FEF_{25-75%}. In addition, it sometimes includes the measurement of maximum voluntary ventilation (MVV). A graphic representation (spirogram) of the maneuver should be a part of the results. Either a volume-time or flow-volume display is acceptable. Other parameters that may be obtained by spirometry include FEF_{max} (PEF), FEF_{75%}, FEF_{50%}, FEF_{25%}, FIF_{50%}, and FIF_{max} (PIF).

S 3.0 SETTING:

These guidelines should be applied to spirometry performed by trained health-care professionals

3.1 in the pulmonary function or research laboratory;

3.2 at the bedside, in acute, subacute, extended care, and skilled nursing facilities;

3.3 in the clinic, treatment facility, and physician's office;

3.4 in the workplace or home;

3.5 for public screening.

S 4.0 INDICATIONS:

The indications for spirometry(4-8) include the need to

4.1 detect the presence or absence of lung dysfunction suggested by

history or physical signs and symptoms (eg, age, smoking history, family history of lung disease, cough, dyspnea, wheezing) and/or the presence of other abnormal diagnostic tests (eg, chest radiograph, arterial blood gas analysis);

4.2 quantify the severity of known lung disease;

4.3 assess the change in lung function over time or following administration of or change in therapy;

4.4 assess the potential effects or response to environmental or occupational exposure;

4.5 assess the risk for surgical procedures known to affect lung function;

4.6 assess impairment and/or disability (eg, for rehabilitation, legal reasons, military).

S 5.0 CONTRAINDICATIONS:

The requesting physician should be made aware that the circumstances listed in this section could affect the reliability of spirometry measurements. In addition, forced expiratory maneuvers may aggravate these conditions, which may make test postponement necessary until the medical condition(s) resolve(s).

Relative contraindications(9,10) to performing spirometry are

5.1 hemoptysis of unknown origin (forced expiratory maneuver may aggravate the underlying condition);

5.2 pneumothorax;

5.3 unstable cardiovascular status (forced expiratory maneuver may worsen angina or cause changes in blood pressure) or recent myocardial infarction or pulmonary embolus;

5.4 thoracic, abdominal, or cerebral aneurysms (danger of rupture due to increased thoracic pressure);

5.5 recent eye surgery (eg, cataract);

5.6 presence of an acute disease process that might interfere with test performance (eg, nausea, vomiting);

5.7 recent surgery of thorax or abdomen.

S 6.0 HAZARD/COMPLICATIONS:

Although spirometry is a safe procedure, untoward reactions may occur, and the value of the information anticipated from spirometry should be weighed against potential hazards. The following have been reported anecdotally:

6.1 pneumothorax;

6.2 increased intracranial pressure;

6.3 syncope, dizziness, light-headedness;

6.4 chest pain;

6.5 paroxysmal coughing;

- 6.6** contraction of nosocomial infections;
- 6.7** oxygen desaturation due to interruption of oxygen therapy;
- 6.8** bronchospasm.

S 7.0 LIMITATIONS OF METHODOLOGY/ VALIDATION OF RESULTS:

7.1 Spirometry is an effort-dependent test that requires careful instruction and the cooperation of the test subject. Inability to perform acceptable maneuvers may be due to poor subject motivation or failure to understand instructions. Physical impairment and young age (eg, children < 5 years of age) may also limit the subject's ability to perform spirometric maneuvers. These limitations do not preclude attempting spirometry but should be noted and taken into consideration when the results are interpreted.

7.2 The results of spirometry should meet the following criteria for number of trials, acceptability, and reproducibility. The acceptability criteria should be applied before reproducibility is checked.

7.2.1 Number of trials: A minimum of 3 acceptable FVC maneuvers should be performed.(3) If a subject is unable to perform a single acceptable maneuver after 8 attempts, testing may be discontinued. However, after additional instruction and demonstration, more maneuvers may be performed depending on the subject's clinical condition and tolerance.

7.2.2 Acceptability: A good 'start-of-test' includes:

7.2.2.1 an extrapolated volume of < or = 5% of the FVC or 150 mL, whichever is greater;

7.2.2.2 no hesitation or false start;

7.2.2.3 a rapid start to rise time.

7.2.3 Acceptability: no cough, especially during the first second of the maneuver.

7.2.4 Acceptability: no early termination of exhalation.

7.2.4.1 A minimum exhalation time of 6 seconds is recommended, unless there is an obvious plateau of reasonable duration (ie, no volume change for at least 1 second) or the subject cannot or should not continue to exhale further.(3)

7.2.4.2 No maneuver should be eliminated solely because of early termination. The FEV₁ from such maneuvers may be valid, and the volume expired may be an estimate of the true FVC, although the FEV₁/FVC and FEF_{25-75%} may be overestimated.

7.2.5 Reproducibility:

7.2.5.1 The two largest FVCs from acceptable maneuvers should not vary by more than 0.200 L, and the two largest FEV₁s from acceptable maneuvers should not vary by more than 0.200 L.

Note: The ATS has changed its recommendations from those made in

the 1987 ATS guideline⁽²⁾ (a reproducibility criterion of 5% or 0.100 L, whichever is larger). This change is based on evidence from Hankinson and Bang suggesting that intrasubject variability is independent of body size and that individuals of short stature are less likely to meet the older criterion than are taller subjects.⁽¹¹⁾ In addition, the 0.200-L criterion is simple to apply. However, there are two concerns with this change. The first is whether the 0.200-L criterion is too permissive in shorter individuals (eg, children). Enright and co-workers⁽¹²⁾ reported a failure rate of only 2.1% in 21,432 testing sessions on adults using the 5% or 100-mL criterion. In addition, they found that only 0.4% of test sessions failed to meet relaxed criteria of 5% or 200 mL. These failure rates are much lower than the 5-15% failure rates reported by Hankinson and Bang.⁽¹¹⁾ Enright and co-workers did not study children, but there was some height overlap in the two studies. Thus, we are not convinced that the 5% rule is inappropriate when applied to shorter individuals. Indeed, Hankinson and Bang stated in their report "...it appears that the technician appropriately responded to the lack of a reproducible or acceptable test result by obtaining more maneuvers from these subjects." The second concern is that the 0.200-L criterion may be too rigid for very tall individuals (eg, height > 75 inches). Hankinson and Bang did not study subjects taller than 190 cm (ie, 75 inches). In order to send a consistent message, we recommend the ATS reproducibility criterion but urge practitioners: (a) to use this criterion as a goal during data collection and not to reject a spirogram solely on the basis of its poor reproducibility, (b) to exceed the reproducibility criterion whenever possible because it will decrease inter- and intralaboratory variability, and (c) to comment in the written report when reproducibility criteria cannot be met.

7.3 Maximum voluntary ventilation (MVV) is the volume of air exhaled in a specified period during rapid, forced breathing.⁽³⁾ This measurement is sometimes referred to as the maximum breathing capacity (MBC).

7.3.1 The period of time for performing this maneuver should be at least 12 seconds but no more than 15 seconds, with the data reported as L/min at BTPS.

7.3.2 At least two trials should be obtained, and the two highest should agree within $\pm 10\%$.

7.4 The use of a nose clip for all spirometric maneuvers is strongly encouraged.

7.5 Subjects may be studied in either the sitting or standing position. Occasionally, a subject may experience syncope or dizziness while performing the forced expiratory maneuver. Thus, the sitting position may be safer. If such a subject is standing, an appropriate chair (ie, with arms and not on rollers) should be placed behind the subject in

the event that he or she needs to be seated quickly. When the maneuver is performed from a seated position, the subject should sit erect with both feet on the floor, and be positioned correctly in relation to the equipment. Test position should be noted on the report.

7.6 Spirometry is often performed before and after inhalation of a bronchodilator.

7.6.1 The drug, dose, and mode of delivery should be specifically ordered by the managing physician or determined by the laboratory and should be noted in the report.

7.6.2 The length of the interval between administration of the bronchodilator and postbronchodilator testing varies among laboratories,(13-17) but there appears to be more support for a minimum interval of 15 minutes for most short and intermediate-acting beta-2 agonists.(14-17) This does not guarantee that peak response will be determined, and underestimation of peak bronchodilator response can occur.

7.6.3 Subjects who use inhaled short-acting bronchodilators should be tested at least 4 to 6 hours after the last use of their inhaled bronchodilator to allow proper assessment of acute bronchodilator response. Long-acting inhaled bronchodilators may need to be withheld for a more extended period. Subjects should understand that if they need to administer their bronchodilator prior to the test because of breathing problems, they should do so. Bronchodilators taken on the day of testing should be noted in the report. Table 1 lists commonly used drugs that may confound assessment of acute bronchodilator response and the recommended times for withholding.

Table 1. Recommended Times for Withholding Commonly Used Bronchodilators When Bronchodilator Response Is To Be Assessed*

| Drug | Withholding Time (hours) |
|----------------|--------------------------|
| salmeterol | 12 |
| ipratropium | 6 |
| terbutaline | 4-8 |
| albuterol | 4-6 |
| metaproterenol | 4 |
| isoetharine | 3 |

**Based on consensus of committee and known duration of action*

7.6.4 Interpretation of response to a bronchodilator should take into account both magnitude and consistency of change in the pulmonary function data. The recommended criterion for response to a bronchodilator in adults for FEV1 and FVC is a 12% improvement from

baseline and an absolute change of 0.200 L.(18) However, because the peak effect of the drug may not always be determined, the inability to meet this response criterion does not exclude a response. In addition, dynamic compression of the airways during the forced expiratory maneuver may mask bronchodilator response in some subjects, and the additional measurement of airway resistance and calculation of specific conductance and resistance may provide documentation of airway responsiveness.(19)

7.7 Reporting of results:

7.7.1 The largest FVC and FEV1 (at BTPS) should be reported even if they do not come from the same curve.

7.7.2 Other reported measures (eg, FEF25-75% and instantaneous expiratory flowrates, such as FEFmax and FEF50%) should be obtained from the single acceptable 'best-test' curve (ie, largest sum of FVC and FEV1) and reported at BTPS.

7.7.3 All values should be recorded and stored so that comparison for reproducibility and the ability to detect spirometry-induced bronchospasm (as evidenced by a worsening in spirometric values with successive attempts-and not related to fatigue) are simplified.

7.7.4 The highest MVV trial should be reported.

7.8 Subject demographics and related information:

7.8.1 Age: The age on day of test should be used.

7.8.2 Height: The subject should stand fully erect with eyes looking straight ahead and be measured with the feet together without shoes. An accurate measuring device should be used. For subjects who cannot stand or who have a spinal deformity (eg, kyphoscoliosis), the arm span from finger tip to finger tip with arms stretched in opposite directions can be used as an estimate of height.(20)

7.8.3 Weight: An accurate scale should be used to determine the subject's weight while wearing indoor clothes but without shoes.

7.8.4 Race: The race or ethnic background of the subject should be determined and reported to help ensure the use of appropriate reference values and appropriate interpretation of data.

7.8.5 The time of day, equipment or instrumentation used, and name of the technician administering the test should be recorded.

7.9 Open- and closed-circuit testing:

7.9.1 Open circuit: The subject takes a maximal inspiration from the room, inserts the mouthpiece into the mouth, and then blows out either slowly (SVC) or rapidly (FVC) until the end-of-test criterion is met. Although the open-circuit technique works well for some subjects, others have difficulty maintaining a maximum inspiration while trying to position the mouthpiece correctly in the mouth. These subjects may lose some of their vital capacity due to leakage prior to the expiratory maneuver.(11)

7.9.2 Closed-circuit: The subject inserts the mouthpiece into the mouth and breathes quietly for no more than 5 tidal breaths, takes a maximal inspiration from the reservoir, and then blows out either slowly (SVC) or rapidly (FVC) until the end-of-test criterion is met. This rebreathing technique is preferred if the spirometer system permits because it (1) allows the subject to obtain a tight seal with the mouthpiece prior to inspiration and (2) allows evaluation of the volume inspired.

S 8.0 ASSESSMENT OF NEED:

Need is assessed by determining that valid indications are present.

S 9.0 ASSESSMENT OF TEST QUALITY:

Spirometry performed for the listed indications is valid only if the spirometer functions acceptably and the subject is able to perform the maneuvers in an acceptable and reproducible fashion. All reports should contain a statement about the technician's assessment of test quality and specify which acceptability criteria were not met.

9.1 Quality control:(21)

9.1.1 Volume verification (ie, calibration): at least daily prior to testing, use a calibrated known-volume syringe with a volume of at least 3 L to ascertain that the spirometer reads a known volume accurately. The known volume should be injected and/or withdrawn at least 3 times, at flows that vary between 2 and 12 L/s (3-L injection times of approximately 1 second, 6 seconds, and somewhere between 1 and 6 seconds). The tolerance limits for an acceptable calibration are $\pm 3\%$ of the known volume. Thus, for a 3-L calibration syringe, the acceptable recovered range is 2.91-3.09 L. We encourage the practitioner to exceed this guideline whenever possible (ie, reduce the tolerance limits to $< \pm 3\%$)

9.1.2 Leak test: Volume-displacement spirometers must be evaluated for leaks daily. One recommendation is that any volume change of more than 10 mL/min while the spirometer is under at least 3-cm-H₂O pressure be considered excessive.(22)

9.1.3 A spirometry procedure manual should be maintained.

9.1.4 A log that documents daily instrument calibration, problems encountered, corrective action required, and system hardware and/or software changes should be maintained.

9.1.5 Computer software for measurement and computer calculations should be checked against manual calculations if possible. In addition, biologic laboratory standards (ie, healthy, nonsmoking individuals) can be tested periodically to ensure historic reproducibility, to verify software upgrades, and to evaluate new or replacement spirometers.

9.1.6 The known-volume syringe should be checked for accuracy at

least quarterly using a second known-volume syringe, with the spirometer in the patient-test mode. This validates the calibration and ensures that the patient-test mode operates properly.

9.1.7 For water-seal spirometers, water level and paper tracing speed should be checked daily. The entire range of volume displacement should be checked quarterly.(21)

9.2 Quality Assurance: Each laboratory or testing site should develop, establish, and implement quality assurance indicators for equipment calibration and maintenance and patient preparation. In addition, methods should be devised and implemented to monitor technician performance (with appropriate feedback) while obtaining, recognizing, and documenting acceptability criteria.

S 10.0 RESOURCES:

10.1 Equipment: The spirometer must meet or exceed the requirements proposed by the ATS and must be calibrated appropriately.(3) Spirometers should produce a paper record of volume-time and/or flow-volume displays. Reference values should be appropriate for the population of subjects tested and should be validated by testing a group of healthy, nonsmoking subjects with the same mix of age, gender, and height used in the reference study.(18)

10.2 Personnel: Spirometry should be administered under the direction of a doctor (MD, DO, or PhD) specifically trained in pulmonary function testing. The value of spirometry results can be compromised by poor patient instruction secondary to inadequate technician training. Thus, technicians should have documented training, with continued competency assessments in spirometry administration and recognition of causes for errors encountered in the testing process and a sound understanding of physiologic effects caused by bronchodilators. They should be trained in basic life support and emergency procedures appropriate to the setting.(23) Spirometry can be administered by persons who meet criteria for either Level I or Level II.

10.2.1 Level I: Persons trained in and with demonstrated ability to perform spirometry. Minimum educational requirements for Level-I personnel should be a high school diploma. One or more years of college or equivalent training and strong mathematical skills are encouraged. We recommend that Level-I personnel take an approved training course and have at least 6 months of supervised training. Test quality should be reviewed by Level-II personnel or a physician, with feedback on an ongoing basis.

10.2.2 Level II: Persons with formal education (2 or more years of college-level studies in biologic sciences and/or mathematics) and training that includes 2 or more years of experience administering

spirometry. One of the following credentials is recommended: Certified Respiratory Therapy Technician (CRTT), Registered Respiratory Therapist (RRT), Certified Pulmonary Function Technologist (CPFT), Registered Pulmonary Function Technologist (RPFT).

S 11.0 MONITORING:

The following should be evaluated during the performance of spirometric measurements to ascertain the validity of the results:(3,24)

11.1 acceptability of maneuver and reproducibility of FVC, FEV1.(25)

11.2 level of effort and cooperation by the subject.

11.3 equipment function or malfunction (eg, calibration).

11.4 The final report should contain a statement about test quality.

11.5 Spirometry results should be subject to ongoing review by a supervisor, with feedback to the technologist.(12) Quality assurance and/or quality improvement programs should be designed to monitor technician competency, both initially and on an ongoing basis.

S 12.0 FREQUENCY:

The frequency with which spirometry is repeated should depend on the clinical status of the subject and the indications for performing the test.

S 13.0 INFECTION CONTROL:

Spirometry is a relatively safe procedure, but the possibility of cross-contamination exists, either from the patient-patient or the patient-technologist interface. The following guidelines should be applied whenever spirometry is performed.

13.1 Universal Precautions(26,27) should be applied in all instances in which there is the potential for exposure to blood and body fluids. The appropriate use of barriers (eg, gloves) and handwashing are recommended.(28-30)

13.2 Due to the nature of forced expiratory maneuvers and the likelihood of coughing when spirometry is performed by subjects who may have active infection with *M. tuberculosis* or other airborne organisms, the following precautions are recommended:

13.2.1 The room in which spirometry is performed should meet or exceed the recommendations of U.S. Public Health Service(31) for air changes and ventilation. The ideal situation is an area in the testing department specially ventilated for isolation patients and incorporating filtration or ultraviolet decontamination of air. If this is not possible, the patient should be returned to the isolation room as soon as possible or, alternatively, tested at the bedside using an acceptable spirometer.

13.2.2 When procedures involve patients with suspected infectious

airborne diseases, barrier protection (eg, mask or personal respirator meeting regulatory agency requirements) is required.(32)

13.2.3 The use of gloves or other impermeable barriers is encouraged when contaminated equipment is handled.(3)

13.2.4 The air in a volume-displacement spirometer should be flushed out at least 5 times between subjects.(3)

13.2.5 Equipment can be reserved for the sole purpose of testing infected patients (eg, those with *M. tuberculosis* or methicillin-resistant *Staphylococcus aureus*).

13.2.6 Infected patients can be tested at the end of the day or week and equipment can then be disassembled and disinfected.

13.2.7 Special precautions may need to be taken for immunocompromised subjects.

13.3 The mouthpiece, tubing, and any parts of the spirometer that come into direct contact with the subject should be disposable or be disinfected between patients. It is unnecessary to routinely clean the interior surface of volume-displacement spirometers.

13.3.1 The open-circuit technique (ie, no rebreathing on mouthpiece or through breathing tube) reduces the risk of infection to the patient but not to the technician.(31,32) The mouthpiece should be changed between patients, but it is not necessary to change breathing tube or hose, unless excessive water condensation occurs.(3)

13.3.2 If the closed-circuit technique (subject rebreathes on mouthpiece and through the breathing tube and spirometer) is used, the breathing tube and mouthpiece should be disposed of or disinfected between subjects.(3)

13.3.3 For flow-sensing systems in which no breathing tube is interposed between the subject and the device, inspiration from the device should be avoided or the flow-sensing element and interior tubing should be disinfected between subjects.

13.4 Bacteria filters are widely used in pulmonary function laboratories, although the need for such filters and their effectiveness is not well documented. These filters impose added resistance and have been reported to have a statistical but not clinically meaningful effect on pulmonary function test results.(33,34) If in-line filters are used during spirometry, we recommend that the equipment be calibrated with the filter installed and that the filter be discarded after use on a single subject. The use of in-line filters does not eliminate the need for regular cleaning and disinfection and does not guarantee that transmission of disease(s) cannot occur.

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